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Use of the Artificial Kidney in Human Patients

Dept. of Navy, Office of Naval Research. NR 115-820

Final Report

The work covered by this contract can be subdivided into three major phases: (1) Methodology, (2) Studies involving animals and, (3) Studies with patients.

Methodology

Procedures were developed for the simultaneous determination of plasma volume, sodium and bromine spaces. These estimates were accomplished using three radioactive isotopes simultaneously: Iodine^{131} (as iodinated human albumin), sodium^{24}, and bromine^{82}. The method of determining the fluid compartments discussed above consist of giving a mixture of radioactive sodium and bromide intravenously and withdrawing blood samples four and a half and five hours later. After the last blood sample is obtained a solution containing radioactive iodinated human albumin is injected through the same needle. Ten minutes later the last blood specimen is withdrawn and used for the determination of the plasma volume (blood volume too if a hematocrit is obtained or whole blood is counted). By taking advantage of the different decay factors for the three isotopes used, and counting the same samples at various times, it is possible by means of simultaneous equations to obtain the content of each of the individual isotopes. With this known, the determination of the sodium and bromide spaces or the plasma volume requires the use of the simple dilution formula.

Sixty-one studies have been carried out on patients using these techniques. Twenty-six of the patients studied had no abnormalities of fluid or electrolyte metabolism and twenty-nine additional patients were studied because they presented clinical evidence of aberrations of fluid and/or electrolyte distribution. Studies were repeated on six of the latter patients.

Modifications of the surgical and clinical procedures used for the artificial kidney in the carrying out of the dialysis will be discussed under the studies involving patients.

Animal Studies

A series of twelve bilaterally nephrectomized dogs were given large amounts of electrolyte poor fluids (10 per cent glucose in distilled water) intravenously. These conditions simulated the clinical history offered by many anuric patients who were sent to our institute for dialysis. Body weight, sodium and chloride concentration of the plasma, along with sodium, bromine and inulin spaces were normally determined before the nephrectomy and overhydration; and at various intervals postoperatively (Table I). Due to the unpredictable death of the animals no studies could be made using the artificial kidney, or a hypertonic sodium-chloride solution to counteract these changes. During the period of overhydration the sodium level of plasma fell from a normal value of 140 - 150 to 106 - 116 mEq./L. There was also a fall in the chloride concentration which paralleled the fall of sodium. On the other hand, the potassium content of the plasma increased in spite of the hemodilution (presumably due to an increased catabolism of body tissues). These animals also showed increases in the inulin, sodium and bromide

spaces. The rather large control values for the latter two compartments, reported here, are due to the six hour period used for the equilibration of the ions. These studies indicate that animals and patients who have anuria and are given large amounts of water must also receive electrolytes and a high carbohydrate and fat intake to minimize cellular breakdown.

Because of the confusion as to the etiology of the hyperchloremic acidosis which develops in some patients following ureterosigmoid transplants, studies were carried out in dogs in which the ureters were implanted into the colon. During these studies the animals were maintained on various diets, high and low in chloride, given anion exchange resins, and subjected to periods of dehydration. It was found that dehydration was one of the most potent methods of producing hyperchloremic acidosis. In addition to the blood chemistry studies (sodium, potassium and chloride levels, pH and carbon dioxide content), space determinations were made using radioactive sodium and bromine. An important corollary to this problem was also studied in which the rate of transfer of sodium and bromine into and out of the lumen of the colon of dogs was measured. For this work, solutions containing radioactive sodium and bromine were instilled into blind loops of intestine of dogs and at intervals aliquots were removed for the assay of both the chemical constituents and remaining activity. The last two projects are being prepared for publication by Drs. Krieger, Persky and DesPrez. In conjunction with this study, four patients exhibiting hyperchloremic acidosis, following ureterosigmoid transplant, were studied. The impression gained from this work was that although renal disfunction is an important factor, the acidosis or control of it could be governed by dietary measures.

Patient Work

The artificial kidney was employed with two views in mind, the first being the treatment of patients with acute renal failure, and the second was to educate interns, residents and staff members as to its principles, method of use, and application to clinical problems. Ten to twelve different members of the house staff participated in the dialysis and one physician (Dr. Eudore Savoie), who was sponsored by the Canadian Government, spent almost a year studying electrolyte, water balance, and the use of the artificial kidney with us. In addition, members of the medical classes of Western Reserve University, College of Medicine, and the nurses from the Francis Payne Bolton School of Nursing observed some of the runs on the artificial kidney.

A summary of ten patients studied up to November 19, 1953 is given in Table II. The patients included those from our hospital population and patients sent specifically to us for dialysis from other institutes, both within and outside Ohio. Two runs were made in New York City, where the artificial kidney was sent and operated by Dr. Jack Leonards. Beside treating acute renal shutdowns, the kidney has found application in removing soluble toxic substances from the body, e.g. salicylic acid and mercury salts. Also, many of the clinicians were quite impressed with its ability to remove excess water from patients and frequently considered it the method of choice in rapidly correcting a grossly abnormal electrolyte or water balance.

The methodology developed in carrying out the dialysis concerned itself mainly in inserting the catheters in such a manner that bleeding from the site of insertion would be minimum. The flow of blood to the artificial kidney is adequate if the catheters are inserted into the saphenous vein (the catheters are advanced until they enter the inferior vena cava) or from the radial artery. Also, undertaking the dialysis at an optimum time in the clinical course of the disorder was believed to be more successful than waiting until all conservative methods have proven fruitless before beginning a dialysis.

In addition to treating patients with renal shutdown by means of the artificial kidney, studies w re carried out in which the instrument was used to remove water from certain individuals who were overhydrated. Under present conditions of operation, the use of an artificial kidney of Skeggs-Leonards type appears to be a safe procedure. No deaths occurred which could be attributed to the dialysis procedure, though only ten patients were subjected to dialysis during the time of the contract.

The following persons have come to our laboratories to obtain information concerning the Skeggs-Leonards kidney: Dr. Eudore Savoie, Hotel Dieu, Montreal, Canada; Dr. Frank Maher, Mayo Clinic; Dr. Curtis Artz, Dr. Eric Reiss and Dr. Lamont Danzig, Brooke Army Medical Center; Dr. Per Schampe, Royal Veterinary College, Copenhagen, Denmark; Dr. Walter Hoffman, University of Tennessee; Dr. Belding Schriber, Veterans Hospital, Seattle, Washington; Dr. Peter Salisbury, Cedars of Lebanon Hospital, Los Angeles; and Dr. Theodore Weichselbaum, Washington University, St. Louis. Except for the first three individuals all others possess this type of dialyzing unit (Skeggs-Leonards).

From our point of view this was a most profitable year. Increased interest in dialysis was made possible and the scope of the artificial kidney was increased from the use of acute renal failure to the removal of toxic substances and to the extraction of fluid and electrolytes from "waterlogged" patients.

[illegible] and the Administration of 10% Glucose in Distilled Water

	Time after nephrectomy		10% Glucose in H_2O given I.V.	Volume of Vomitus		Serum Electrolytes			Loss in vomitus (total mEq.)			Volume of Distribution
Dog No.	Weight	Days	Cumulative	Daily	Cumulative	Na	K	Cl	Na	K	Cl	Inulin
329	13.0	0	0			153	4.6	111				2950
	11.8	1	1250	575		160	8.0	124	60	35	120	
	12.2	2	2500	155	730	144	8.0	109	8	3	20	
	13.2	3	3750	207	937	131	8.6	91	28	5	32	
	13.2	4	4950	393	1330	124	9.7	68	20	14	43	
	12.7	5	4950	900	2230	110	9.1	49	63	24	148	
280	14.8	0				150	4.7	114				3500
	14.8	1	1200			157	6.0	116				
	15.5	2	2750	95		149	5.9	113	7	3		
	16.4	3	4000	455	550	121	4.5	82	23	7		
	17.0	4	5200	700	1250	130	5.7	76	41	13		
	17.7	5	6350			116	6.1	72				5800
314	11.6	0				147	5.4					2850
	11.4	1	1300	210		158	6.2		15	5.2		
	11.6	2	2350	355	565	138	5.1		29	7.1		
	11.8	3	3400	600	1165	123	5.3		31	12.0		
	12.1	4	4200			114	6.6					

	Time after [illegible]		10% Glucose in [illegible] given I.V.	Volume of [illegible]		[illegible]			Volume of Distribution		
Dog No.	Weight	Days	Cumulative	Actual	Cumulative	Na	K	Cl	Na^{24}	Br	Inulin
332	24.4	0				150	4.6	120	8010	8560	5500
	24.4	1	1500		150	150		124			
	24.6	2	3150	250	400	132		101			
	25.5	3	4650	700	1100	138	4.8	71			
	25.5	4	6150	500	1600	116	5.2	62			
	26.4	5	7650	500	2100	109	6.0	69			
	25.9	6	7850			106	7.7	57	9380	10,600	7300
307	13.2	0				141		110			2650
	13.2	1	1200	150	150						
	13.4	2	2500	60	210	134					
	13.6	3	3700	450	660			95			
	14.1	4	3900	690	1350	130		89	5007		3750
	13.0	5	4900	150	1500	125		85			
	13.2	6	6100	[illegible]		120					
	13.0	7	6700		2300	115		65			
269	18.7	0	0			140		106	5600	4170	3900
	18.8	2	2750		100	134	7.0	100			
	18.8	3	3750			130	7.6	95			
	18.6	4	4750		300	129	8.1	89			
	19.3	5	5850		430	116	9.4	76	7100	8200	[illegible]

	Time after nephrectomy		10% glucose in H2O given I.V.	Volume of Vomitus		Serum Electrolytes		Loss in vomitus (total mEq.)	Amount Distrib.
Dog No.	Weight	Days	Cumulative	Actual	Cumulative	Na	K	Na	Inulin
341	13.6	0				150	4.2	0	2850
	13.0	1	1350	25		158	6.5	5	
	14.1	2	2450	1150	1175	134		22	
	13.9	3	3500	225	1400	125	5.4	6	
	14.6	4	4500	200		118	5.2	10	
	15.0	5	died		1600	103	8.8	43 mEq. (total	4300

Table II. Patients Undergoing Hemodialysis

No.	Initials	Sex	Age	Disorder	Dehydrated
1	A.H.	F	44		
2	H.A.	F	29	Mercury Bichloride Poisoning	6000 ml.
3	L.A.	F	43	Incompatible transfusion	1000 ml.
4	M.K.	F	31	Incompatible transfusion	
5	D.W.	F	6	Nephrosis	1250 ml.
6	L.J.	M	70	Methyl Salicylate Poisoning	
7	D.E.	F	18	Incompatible transfusion	
8	W.F.	M	67	Liver Coma, Jaundice, C.A.	
9	C.D.	F	23	Caesarian Section, Incompatible transfusion	
10	I.S.*	F	50	Postoperative anuria (dialyzed two times)	

* Carried out in New York City